N94-21348

ARRAY SIMULATIONS PLATFORM (ASP) PREDICTS NASA DATA LINK MODULE (NDLM) PERFORMANCE[1]

Allen David Snook
Loral Aerosys SEAS

Through a variety of imbedded theoretical and actual antenna patterns, the array simulation platform (ASP) enhanced analysis of the array antenna pattern effects for the KTx (Ku-Band Transmit) service of the NDLM (NASA Data Link Module). The ASP utilizes internally stored models of the NDLM antennas and can develop the overall pattern of antenna arrays through common array calculation techniques.

ASP expertly assisted in the diagnosing of element phase shifter errors during KTx testing, and was able to accurately predict the overall array pattern from combinations of the four internally held element patterns. This paper provides an overview of the use of the ASP software in the solving of array mis-phasing problems.

I. Introduction

One path of development for highly directional antenna assemblies is the use of a matrix, or array, or antenna elements arranged in such a manner as to produce a highly focused beam of transmit energy, or to serve as a highly selective receive antenna. The use of antenna arrays to perform these functions dates back to the 1920s.[2]

Similarly, the use of the modern computer and specialty software to calculate patterns for arrays of antenna elements is not a new science, either. The ASP differs from previous work not on the merits of it's code, but the application of the code towards the solving of array alignment problems.

[1] Developed for NDLM testing in support of R. Stelmaszek, GSFC Code 531.4, Networks Test Section, and K. Perko, GSFC Code 737.2, Instrument and Advanced Development Section.

[2] W. L. Stutzman and G. A. Thiele, "Antenna Theory and Design," Wiley, 1981, Ch. 3

II. Ideal Application

The NASA Data Link Module (NDLM) array antenna, pictured in Figure 1, is comprised of several individual communications antenna experiments. Of these, the KTx (Ku-Band Transmit) portion of the NDLM is of unique interest. The KTx is the only subsystem on the NDLM package that possesses a beam-steering capability. Through the use of mechanical phase shifters, the four elements comprising the KTx subsystem can be moved in phase relative to each other. The elements of the KTx are configured in an arrangement known as a **planar array,** with a rectangular disposition.

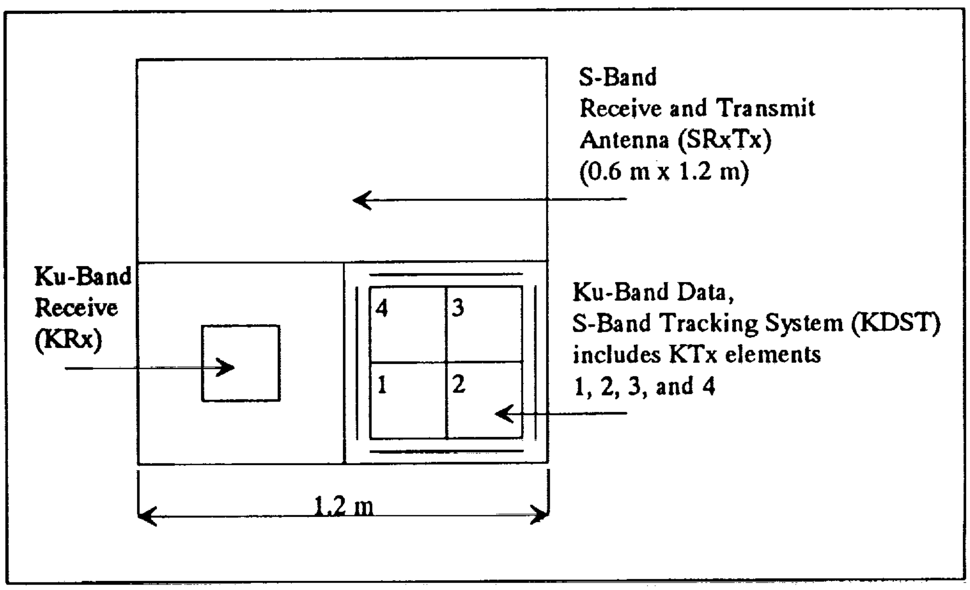


Figure 1. NDLM illustrated

The solitary data structure upon which the ASP software acts is, of course, the antenna element specifications. The variables of interest for each antenna element are 1) location in x, y, z space, 2) the relative amplitude, 3) the relative phase, and 4) the element type. As illustrated in Figure 2, the KTx element centers, form a square in the xz plane, with the basis of the square as 0.279 m. (Element spacing, at the principal KTx operating frequency of 15.0034 GHz, is about 14λ).[3] As readers with experience in array construction are aware, that large a spacing will immediately contribute to the creation of numerous additional lobes in the overall array pattern.

[3] λ, wavelengths

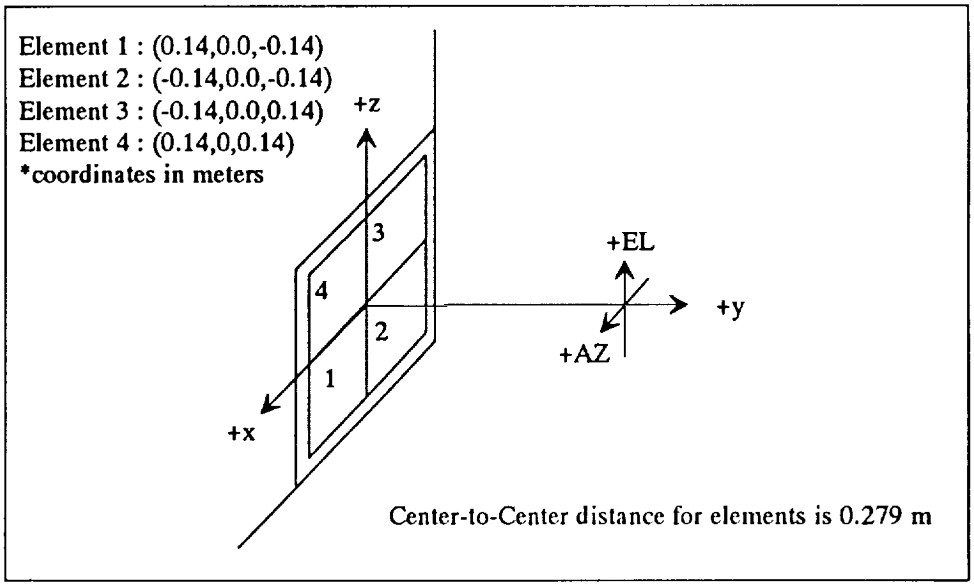


Figure 2. KTx geometry

It is not the purpose of this paper to provide a treatise on array antenna dynamics, as much work has already been covered on the subject. For a comprehensive discussion of the subject, the reader is referred to the previously referenced text by Stutzman (1981). For the purposes of this paper, a modest understanding of array factors is recommended.

The ASP was asked to prepare an analysis of a planar array of four isotropic sources, $F(\theta,\phi)=1.0$, with an inter-element basis of 27.9 cm, an operating frequency of 15.0034 GHz, identical relative amplitudes and phases. This exercise performs, in essence, an analysis of the KTx, with the effects of the element patterns removed. The array pattern is given in Figure 3.

The previously mentioned grating lobes would appear to ruin the chances of any directivity ever being obtained from an antenna with this geometry, but bear in mind the removal of the effect of the KTx element pattern. KTx element patterns were taken on several occasions, and the average pattern data for each element in azimuth and elevation was collected and integrated into the code for ASP. Off-axis data was estimated using an interpolation function, as no off-axis data was readily available for the elements. The patterns were discretized in half-degree increments, with linear interpolation providing the pattern values for the remainder of the curves. The patterns for each element are presented in Figure 4a through d for elements 1 through 4, respectively.

Detailed Printout
Phase 1 = 0.000 degrees, Amplitude 1 = 1.000 (0.0000 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 1.000 (0.0000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 1.000 (0.0000 dB)
Phase 4 = 0.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	0	-1	-1	-3	-6	-14	-5	-2	-1	-1	0	-1	-1	-2	-5	-14	-6	-3	-1	-1	0
3.2	-1	-1	-2	-4	-7	-15	-6	-3	-2	-1	-1	-1	-2	-3	-6	-15	-7	-4	-2	-1	-1
2.8	-3	-3	-4	-5	-8	-17	-7	-5	-4	-3	-3	-3	-4	-5	-7	-17	-8	-5	-4	-3	-3
2.4	-6	-6	-7	-8	-12	-20	-10	-8	-7	-6	-6	-6	-7	-8	-10	-20	-12	-8	-7	-6	-6
2.0	-14	-14	-15	-17	-20	-28	-19	-16	-15	-14	-14	-14	-15	-16	-19	-28	-20	-17	-15	-14	-14
1.6	-5	-5	-6	-7	-10	-19	-9	-7	-6	-5	-5	-5	-6	-7	-9	-19	-10	-7	-6	-5	-5
1.2	-2	-3	-3	-5	-8	-16	-7	-4	-3	-2	-2	-2	-3	-4	-7	-16	-8	-5	-3	-3	-2
0.8	-1	-1	-2	-4	-7	-15	-6	-3	-2	-1	-1	-1	-2	-3	-6	-15	-7	-4	-2	-1	-1
0.4	0	-1	-1	-3	-6	-14	-5	-2	-1	0	0	0	-1	-2	-5	-14	-6	-3	-1	-1	0
0.0	0	0	-1	-3	-6	-14	-5	-2	-1	0	0	0	-1	-2	-5	-14	-6	-3	-1	0	0
-0.4	0	-1	-1	-3	-6	-14	-5	-2	-1	0	0	0	-1	-2	-5	-14	-6	-3	-1	-1	0
-0.8	-1	-1	-2	-4	-7	-15	-6	-3	-2	-1	-1	-1	-2	-3	-6	-15	-7	-4	-2	-1	-1
-1.2	-2	-3	-3	-5	-8	-16	-7	-4	-3	-2	-2	-2	-3	-4	-7	-16	-8	-5	-3	-3	-2
-1.6	-5	-5	-6	-7	-10	-19	-9	-7	-6	-5	-5	-5	-6	-7	-9	-19	-10	-7	-6	-5	-5
-2.0	-14	-14	-15	-17	-20	-28	-19	-16	-15	-14	-14	-14	-15	-16	-19	-28	-20	-17	-15	-14	-14
-2.4	-6	-6	-7	-8	-12	-20	-10	-8	-7	-6	-6	-6	-7	-8	-10	-20	-12	-8	-7	-6	-6
-2.8	-3	-3	-4	-5	-8	-17	-7	-5	-4	-3	-3	-3	-4	-5	-7	-17	-8	-5	-4	-3	-3
-3.2	-1	-1	-2	-4	-7	-15	-6	-3	-2	-1	-1	-1	-2	-3	-6	-15	-7	-4	-2	-1	-1
-3.6	0	-1	-1	-3	-6	-14	-5	-2	-1	-1	0	-1	-1	-2	-5	-14	-6	-3	-1	-1	0

Figure 3. Pattern for an Array of Isotropic Elements, KTx Basis

Detailed Printout
Phase 1 = 0.000 degrees, Amplitude 1 = 1.000 (0.0000 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.000 (-999.0000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.000 (-999.0000 dB)
Phase 4 = 0.000 degrees, Amplitude 4 = 0.000 (-999.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-40	-38	-32	-27	-23	-21	-19	-17	-16	-15	-15	-15	-15	-16	-16	-17	-19	-21	-24	-28	-33
3.2	-35	-34	-28	-22	-18	-16	-14	-12	-11	-10	-10	-10	-10	-11	-11	-12	-14	-16	-19	-23	-28
2.8	-32	-31	-25	-19	-15	-13	-11	-9	-8	-8	-7	-7	-8	-8	-8	-9	-11	-14	-16	-20	-25
2.4	-30	-28	-22	-17	-13	-10	-9	-7	-6	-5	-4	-5	-5	-6	-6	-7	-9	-11	-14	-18	-23
2.0	-28	-26	-20	-14	-11	-8	-7	-5	-4	-3	-2	-2	-3	-3	-4	-4	-7	-9	-12	-16	-21
1.6	-27	-26	-20	-14	-10	-8	-6	-4	-3	-2	-2	-2	-2	-3	-3	-4	-6	-8	-11	-15	-20
1.2	-27	-25	-19	-13	-10	-7	-6	-4	-2	-2	-1	-1	-2	-2	-3	-3	-6	-8	-11	-15	-20
0.8	-26	-25	-19	-13	-9	-7	-5	-3	-2	-2	-1	-1	-1	-2	-2	-3	-5	-8	-10	-14	-19
0.4	-26	-24	-18	-12	-9	-6	-5	-3	-2	-1	0	0	-1	-1	-2	-2	-5	-7	-10	-14	-19
0.0	-25	-24	-18	-12	-8	-6	-4	-2	-1	-1	0	0	-1	-1	-2	-2	-4	-7	-10	-13	-19
-0.4	-26	-24	-18	-12	-9	-6	-5	-3	-2	-1	0	0	-1	-1	-2	-2	-5	-7	-10	-14	-19
-0.8	-26	-25	-19	-13	-9	-7	-5	-3	-2	-2	-1	-1	-1	-2	-2	-3	-5	-8	-10	-14	-19
-1.2	-27	-25	-19	-14	-10	-7	-6	-4	-3	-2	-1	-2	-2	-3	-3	-4	-6	-8	-11	-15	-20
-1.6	-28	-26	-20	-15	-11	-8	-7	-5	-4	-3	-2	-3	-3	-4	-4	-5	-7	-9	-12	-16	-21
-2.0	-29	-28	-22	-16	-12	-10	-8	-6	-5	-5	-4	-4	-5	-5	-6	-6	-8	-11	-14	-17	-22
-2.4	-30	-29	-23	-17	-13	-11	-9	-7	-6	-6	-5	-5	-6	-6	-6	-7	-9	-12	-14	-18	-23
-2.8	-32	-31	-25	-19	-15	-13	-11	-9	-8	-8	-7	-7	-8	-8	-8	-9	-11	-14	-16	-20	-25
-3.2	-35	-33	-27	-21	-18	-15	-14	-12	-10	-10	-9	-9	-10	-10	-11	-11	-14	-16	-19	-23	-28
-3.6	-37	-36	-30	-24	-20	-18	-16	-14	-13	-13	-12	-12	-13	-13	-13	-14	-16	-19	-21	-25	-30

Figure 4a. Element 1 Amplitude Pattern

Detailed Printout
Phase 1 = 0.000 degrees, Amplitude 1 = 0.000 (-999.0000 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 1.000 (0.0000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.000 (-999.0000 dB)
Phase 4 = 0.000 degrees, Amplitude 4 = 0.000 (-999.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-33	-27	-23	-20	-17	-16	-15	-13	-13	-12	-11	-12	-12	-13	-13	-14	-15	-17	-20	-24	-29
3.2	-30	-24	-19	-16	-14	-13	-11	-10	-10	-9	-8	-8	-9	-9	-10	-11	-12	-14	-17	-21	-26
2.8	-28	-22	-17	-14	-12	-10	-9	-8	-7	-7	-6	-6	-7	-7	-8	-9	-10	-12	-15	-18	-24
2.4	-26	-20	-15	-12	-10	-9	-7	-6	-5	-5	-4	-4	-5	-5	-6	-7	-8	-10	-13	-17	-22
2.0	-25	-18	-14	-11	-9	-7	-6	-5	-4	-4	-3	-3	-4	-4	-5	-6	-7	-9	-11	-15	-21
1.6	-24	-17	-13	-10	-8	-6	-5	-4	-3	-3	-2	-2	-2	-3	-4	-5	-6	-8	-10	-14	-20
1.2	-23	-17	-12	-9	-7	-6	-4	-3	-2	-2	-1	-1	-2	-2	-3	-4	-5	-7	-10	-14	-19
0.8	-23	-16	-12	-9	-7	-5	-4	-3	-2	-2	-1	-1	-1	-2	-2	-4	-5	-7	-9	-13	-19
0.4	-22	-16	-12	-9	-6	-5	-4	-2	-2	-1	0	0	-1	-1	-2	-3	-4	-6	-9	-13	-18
0.0	-22	-16	-11	-8	-6	-4	-3	-2	-1	-1	0	0	-1	-1	-2	-3	-4	-6	-9	-12	-18
-0.4	-23	-16	-12	-9	-7	-5	-4	-3	-2	-2	-1	-1	-2	-2	-3	-4	-5	-7	-9	-13	-19
-0.8	-23	-17	-13	-10	-7	-6	-5	-3	-3	-2	-1	-2	-2	-2	-3	-4	-5	-7	-10	-14	-19
-1.2	-24	-18	-13	-10	-8	-7	-5	-4	-3	-3	-2	-2	-3	-3	-4	-5	-6	-8	-11	-14	-20
-1.6	-25	-19	-14	-11	-9	-8	-6	-5	-4	-4	-3	-3	-4	-4	-5	-6	-7	-9	-12	-15	-21
-2.0	-26	-20	-16	-13	-11	-9	-8	-7	-6	-5	-4	-5	-5	-6	-6	-7	-9	-10	-13	-17	-22
-2.4	-28	-21	-17	-14	-12	-10	-9	-8	-7	-6	-6	-6	-6	-7	-7	-8	-10	-12	-14	-18	-23
-2.8	-29	-23	-19	-16	-14	-12	-11	-10	-9	-8	-7	-8	-8	-9	-9	-10	-12	-13	-16	-20	-25
-3.2	-31	-25	-21	-18	-16	-14	-13	-12	-11	-10	-9	-10	-10	-11	-11	-12	-14	-15	-18	-22	-27
-3.6	-34	-28	-23	-20	-18	-16	-15	-14	-13	-13	-12	-12	-13	-13	-14	-15	-16	-18	-21	-24	-30

Figure 4b. Element 2 Amplitude Pattern

Detailed Printout
Phase 1 = 0.000 degrees, Amplitude 1 = 0.000 (-999.0000 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.000 (-999.0000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 1.000 (0.0000 dB)
Phase 4 = 0.000 degrees, Amplitude 4 = 0.000 (-999.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-44	-35	-28	-24	-22	-20	-19	-17	-16	-16	-16	-16	-16	-16	-17	-18	-20	-22	-25	-28	-34
3.2	-39	-29	-22	-18	-16	-15	-13	-12	-11	-11	-10	-10	-11	-11	-12	-12	-14	-17	-20	-23	-28
2.8	-36	-26	-20	-15	-13	-12	-10	-9	-8	-8	-7	-8	-8	-8	-9	-10	-11	-14	-17	-20	-25
2.4	-34	-25	-18	-14	-12	-10	-9	-8	-7	-6	-6	-6	-6	-7	-7	-8	-10	-13	-15	-19	-24
2.0	-32	-23	-16	-12	-10	-9	-7	-6	-5	-4	-4	-4	-4	-5	-5	-6	-8	-11	-13	-17	-22
1.6	-31	-21	-15	-10	-8	-7	-5	-4	-3	-3	-2	-3	-3	-3	-4	-5	-6	-9	-12	-15	-20
1.2	-30	-20	-14	-9	-7	-6	-4	-3	-2	-2	-1	-2	-2	-2	-3	-4	-5	-8	-11	-14	-19
0.8	-29	-20	-13	-9	-7	-5	-4	-3	-2	-1	-1	-1	-1	-2	-2	-3	-5	-8	-10	-14	-19
0.4	-29	-20	-13	-9	-7	-5	-4	-2	-2	-1	-1	-1	-1	-2	-2	-3	-5	-7	-10	-14	-19
0.0	-28	-19	-12	-8	-6	-4	-3	-2	-1	0	0	0	0	-1	-1	-2	-4	-7	-9	-13	-18
-0.4	-29	-19	-13	-8	-6	-5	-3	-2	-1	-1	0	-1	-1	-1	-2	-3	-4	-7	-10	-13	-18
-0.8	-29	-20	-13	-9	-7	-5	-4	-2	-2	-1	-1	-1	-1	-2	-2	-3	-5	-7	-10	-14	-19
-1.2	-30	-20	-13	-9	-7	-6	-4	-3	-2	-2	-1	-1	-2	-2	-3	-3	-5	-8	-11	-14	-19
-1.6	-30	-20	-14	-10	-8	-6	-4	-3	-2	-2	-2	-2	-2	-2	-3	-4	-6	-8	-11	-14	-20
-2.0	-30	-21	-14	-10	-8	-6	-5	-4	-3	-2	-2	-2	-2	-3	-3	-4	-6	-9	-11	-15	-20
-2.4	-33	-23	-17	-12	-10	-9	-7	-6	-5	-5	-4	-5	-5	-5	-6	-7	-8	-11	-14	-17	-22
-2.8	-36	-26	-19	-15	-13	-12	-10	-9	-8	-7	-7	-7	-8	-8	-8	-9	-11	-14	-16	-20	-25
-3.2	-39	-29	-22	-18	-16	-15	-13	-12	-11	-11	-10	-11	-11	-11	-12	-12	-14	-17	-20	-23	-28
-3.6	-43	-33	-27	-23	-21	-19	-17	-16	-15	-15	-15	-15	-15	-15	-16	-17	-19	-21	-24	-27	-33

Figure 4c. Element 3 Amplitude Pattern

```
Detailed Printout
Phase 1 =  0.000 degrees, Amplitude 1 =    0.000 (-999.0000 dB)
Phase 2 =  0.000 degrees, Amplitude 2 =    0.000 (-999.0000 dB)
Phase 3 =  0.000 degrees, Amplitude 3 =    0.000 (-999.0000 dB)
Phase 4 =  0.000 degrees, Amplitude 4 =    1.000 (   0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments:  Levels in dB below reference, -3dB and -10 dB contours indicated
```

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-34	-28	-25	-22	-20	-18	-17	-16	-16	-15	-15	-15	-16	-16	-17	-18	-19	-22	-25	-28	-34
3.2	-29	-23	-20	-17	-15	-14	-12	-11	-11	-10	-10	-10	-11	-11	-12	-13	-14	-17	-20	-23	-30
2.8	-26	-20	-16	-14	-12	-10	-9	-8	-7	-7	-7	-7	-7	-8	-8	-10	-11	-14	-16	-20	-26
2.4	-23	-18	-14	-11	-9	-8	-6	-6	-5	-5	-4	-4	-5	-5	-6	-7	-8	-11	-14	-17	-24
2.0	-22	-16	-13	-10	-8	-6	-5	-4	-4	-3	-3	-3	-4	-4	-5	-6	-7	-10	-13	-16	-22
1.6	-21	-15	-12	-9	-7	-5	-4	-3	-3	-2	-2	-2	-2	-3	-4	-5	-6	-9	-11	-15	-21
1.2	-20	-15	-11	-8	-6	-5	-3	-3	-2	-2	-1	-1	-2	-2	-3	-4	-5	-8	-11	-14	-21
0.8	-20	-14	-11	-8	-6	-4	-3	-2	-2	-1	-1	-1	-1	-2	-3	-4	-5	-8	-10	-14	-20
0.4	-19	-14	-10	-8	-5	-4	-3	-2	-1	-1	0	0	-1	-1	-2	-3	-4	-7	-10	-13	-20
0.0	-19	-13	-10	-7	-5	-4	-2	-1	-1	0	0	0	-1	-1	-2	-3	-4	-7	-10	-13	-20
-0.4	-19	-14	-10	-8	-5	-4	-3	-2	-1	-1	0	-1	-1	-2	-2	-3	-5	-7	-10	-13	-20
-0.8	-20	-14	-11	-8	-6	-4	-3	-2	-2	-1	-1	-1	-2	-2	-3	-4	-5	-8	-11	-14	-20
-1.2	-20	-15	-11	-9	-6	-5	-4	-3	-2	-2	-1	-2	-2	-3	-3	-4	-6	-8	-11	-14	-21
-1.6	-21	-16	-12	-9	-7	-6	-4	-4	-3	-3	-2	-2	-3	-3	-4	-5	-6	-9	-12	-15	-22
-2.0	-22	-16	-13	-10	-8	-6	-5	-4	-4	-3	-3	-3	-4	-4	-5	-6	-7	-10	-13	-16	-22
-2.4	-24	-18	-15	-12	-10	-8	-7	-6	-6	-5	-5	-5	-6	-6	-7	-8	-9	-12	-15	-18	-24
-2.8	-26	-21	-17	-15	-12	-11	-10	-9	-8	-8	-7	-8	-8	-8	-9	-10	-11	-14	-17	-20	-27
-3.2	-29	-23	-20	-17	-15	-13	-12	-11	-11	-10	-10	-10	-11	-11	-12	-13	-14	-17	-20	-23	-29
-3.6	-32	-27	-23	-20	-18	-17	-15	-15	-14	-14	-13	-13	-14	-14	-15	-16	-17	-20	-23	-26	-33

Figure 4d. Element 4 Amplitude Pattern

The ability of the software to model the elements and their environment was limited by the amount of data available upon which to construct the virtual antenna. For this reason, the ASP was unable to make use of element *phase vs. angle* data--only amplitude vs. angle data was available. It would be advantageous, for the sake of competition in the simulated environment, to obtain and implement this data in future uses of the ASP software.

Again, returning to the linear array of two isotropic elements, the replacement of the isotropic elements with the appropriate synthesized KTx patterns results in the following result for an analysis of A1 and A4, again with equal amplitude and phase. In this representation, the A14 elements will produce a pattern affected by array factors only in the elevation pattern. This is a significant improvement in directivity over the isotropic example of Figure 4.

But wait! I thought this KTx was a two dimensional array! Why, yes, it is. Expanding our example to include all four elements, with their individual patterns, identical relative amplitudes and phases, results in the pattern in Figure 6 obtained from ASP at 15.0034 GHz.

Detailed Printout
Phase 1 = 0.000 degrees, Amplitude 1 = 1.000 (0.0000 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.000 (-999.0000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.000 (-999.0000 dB)
Phase 4 = 0.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-36	-31	-27	-24	-22	-20	-18	-17	-16	-16	-15	-15	-16	-16	-17	-18	-19	-22	-25	-28	-34
3.2	-32	-26	-23	-20	-17	-15	-14	-13	-12	-12	-11	-11	-12	-12	-13	-14	-15	-18	-21	-24	-30
2.8	-29	-23	-20	-17	-15	-13	-12	-11	-10	-10	-9	-10	-10	-11	-11	-12	-14	-16	-19	-23	-28
2.4	-27	-21	-18	-16	-14	-13	-12	-11	-11	-10	-10	-10	-11	-11	-12	-13	-14	-17	-20	-23	-29
2.0	-26	-20	-17	-15	-14	-14	-13	-16	-17	-17	-14	-14	-14	-15	-14	-13	-19	-20	-23	-29	-29
1.6	-25	-18	-15	-13	-11	-10	-9	-8	-7	-7	-6	-7	-7	-8	-8	-9	-11	-13	-16	-20	-25
1.2	-23	-18	-14	-12	-9	-8	-6	-5	-4	-4	-3	-4	-4	-5	-5	-6	-8	-10	-13	-17	-22
0.8	-22	-17	-13	-10	-8	-6	-5	-3	-3	-2	-2	-2	-2	-3	-3	-4	-6	-8	-11	-15	-21
0.4	-21	-16	-13	-9	-7	-5	-4	-2	-1	-1	0	-1	-1	-2	-2	-3	-5	-7	-10	-14	-19
0.0	-21	-16	-12	-9	-6	-5	-3	-2	-1	-1	0	0	-1	-1	-2	-3	-4	-7	-10	-13	-19
-0.4	-22	-16	-13	-10	-7	-5	-4	-2	-2	-1	-1	-1	-1	-2	-2	-3	-5	-7	-10	-14	-19
-0.8	-22	-17	-13	-10	-8	-6	-5	-4	-3	-2	-2	-2	-2	-3	-3	-4	-6	-8	-11	-15	-21
-1.2	-24	-18	-14	-12	-10	-8	-7	-5	-5	-4	-4	-4	-4	-5	-5	-6	-8	-10	-13	-17	-22
-1.6	-25	-19	-16	-14	-12	-10	-9	-9	-8	-8	-7	-7	-8	-8	-9	-10	-11	-14	-17	-20	-26
-2.0	-26	-20	-16	-15	-13	-12	-11	-12	-12	-12	-13	-13	-13	-14	-15	-20	-16	-20	-22	-25	-37
-2.4	-28	-22	-19	-17	-15	-14	-13	-12	-12	-11	-11	-11	-11	-12	-12	-13	-15	-17	-20	-24	-29
-2.8	-30	-24	-20	-18	-16	-14	-13	-12	-11	-10	-10	-10	-10	-11	-11	-12	-14	-17	-19	-23	-28
-3.2	-32	-26	-23	-20	-17	-15	-14	-13	-12	-11	-11	-11	-11	-12	-12	-13	-15	-18	-20	-24	-30
-3.6	-34	-29	-25	-22	-19	-18	-16	-15	-14	-13	-13	-13	-13	-14	-14	-15	-17	-20	-22	-26	-32

Figure 5. Pattern for 1 & 4 Synthesized Elements, KTx Basis

Detailed Printout
Phase 1 = 0.000 degrees, Amplitude 1 = 1.000 (0.0000 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 1.000 (0.0000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 1.000 (0.0000 dB)
Phase 4 = 0.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-36	-30	-26	-24	-24	-25	-22	-19	-16	-15	-14	-14	-15	-17	-19	-23	-24	-23	-24	-27	-32
3.2	-33	-26	-22	-20	-20	-23	-20	-15	-13	-12	-11	-11	-12	-13	-16	-23	-21	-20	-21	-24	-29
2.8	-31	-24	-20	-18	-17	-19	-24	-15	-12	-10	-9	-10	-10	-12	-15	-24	-23	-20	-20	-23	-28
2.4	-31	-23	-19	-17	-15	-15	-17	-20	-14	-12	-10	-10	-11	-12	-14	-20	-22	-23	-22	-24	-28
2.0	-33	-24	-20	-18	-16	-15	-15	-16	-16	-15	-13	-13	-15	-17	-19	-18	-20	-19	-21	-25	-29
1.6	-29	-24	-21	-21	-18	-14	-11	-10	-8	-7	-7	-7	-8	-10	-13	-16	-15	-15	-16	-19	-25
1.2	-26	-21	-18	-17	-23	-14	-10	-7	-5	-4	-3	-4	-5	-7	-9	-15	-13	-12	-14	-17	-22
0.8	-24	-19	-16	-14	-16	-14	-9	-6	-4	-2	-2	-2	-3	-5	-8	-15	-11	-11	-12	-15	-20
0.4	-23	-18	-14	-12	-14	-15	-8	-5	-2	-1	-1	-1	-2	-4	-7	-15	-10	-10	-11	-14	-19
0.0	-22	-17	-13	-11	-12	-19	-8	-4	-2	-1	0	0	-2	-3	-6	-16	-10	-9	-10	-13	-18
-0.4	-23	-17	-13	-11	-12	-22	-9	-5	-3	-1	-1	-1	-2	-4	-7	-20	-11	-10	-11	-14	-19
-0.8	-24	-18	-14	-12	-12	-20	-10	-6	-4	-3	-2	-2	-3	-5	-9	-18	-11	-11	-12	-15	-20
-1.2	-26	-19	-15	-13	-14	-19	-12	-8	-5	-4	-4	-4	-5	-7	-11	-15	-13	-13	-14	-17	-22
-1.6	-28	-21	-17	-15	-16	-20	-15	-10	-8	-7	-7	-8	-9	-12	-17	-14	-15	-15	-17	-20	-25
-2.0	-30	-23	-19	-18	-19	-22	-16	-12	-11	-10	-10	-11	-11	-12	-14	-13	-17	-19	-21	-23	-30
-2.4	-32	-26	-23	-22	-24	-21	-17	-15	-13	-12	-11	-11	-11	-12	-14	-15	-25	-21	-22	-24	-29
-2.8	-32	-28	-25	-23	-27	-22	-17	-14	-12	-11	-10	-10	-11	-12	-15	-19	-21	-19	-20	-23	-28
-3.2	-33	-29	-25	-24	-26	-23	-18	-15	-13	-12	-11	-11	-12	-14	-17	-23	-21	-20	-21	-24	-29
-3.6	-36	-31	-27	-26	-27	-26	-20	-17	-15	-14	-13	-14	-15	-16	-20	-26	-23	-22	-23	-26	-31

Figure 6. Complete pattern for all elements active

The overall gain the pattern of Figure 6 should exceed an individial elements gain by 6 dB, due to the summation of the gains (0 dB) of each of the four elements. Of course, if the real world produced series of individual antennas with precisely identical gains, and precisely phased networks to drive those antennas, the work would stop at this point. The true is far stranger than that fiction. For the KTx antennas, the following relative amplitudes were observed for the individual antenna beam peaks (Table 1.) The relative gain measurements were obtained from in-field measurements, and were used throughout KTx ASP calculations.

Table 1. Relative KTx element main-beam gains

Element	Relative Gain (dB)	Decimalized Gain
1	-1.3	0.7413
2	-1.8	0.6607
3	-2.7	0.5370
4	+0.0	1.0000

Further expanding to include these differential gains, and with identical relative phases, results in the following patterns obtained from ASP at 15.0034 GHz:

Detailed Printout
Phase 1 = 0.000 degrees, Amplitude 1 = 0.741 (-1.3001 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.661 (-1.8000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.537 (-2.7003 dB)
Phase 4 = 0.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-36	-30	-26	-24	-24	-27	-25	-19	-17	-15	-14	-14	-15	-17	-19	-25	-27	-24	-25	-28	-33
3.2	-32	-26	-22	-20	-19	-21	-22	-16	-13	-12	-11	-11	-12	-13	-15	-21	-25	-21	-22	-24	-29
2.8	-30	-24	-20	-17	-16	-16	-18	-15	-12	-11	-9	-9	-10	-11	-13	-17	-21	-22	-21	-23	-28
2.4	-29	-22	-18	-16	-14	-13	-14	-15	-15	-12	-10	-10	-10	-11	-12	-15	-17	-23	-28	-26	-29
2.0	-29	-22	-18	-16	-14	-12	-12	-12	-13	-14	-16	-18	-17	-15	-15	-18	-15	-17	-20	-25	-30
1.6	-27	-22	-19	-17	-14	-11	-9	-8	-7	-7	-7	-8	-9	-12	-15	-15	-12	-13	-15	-19	-25
1.2	-25	-20	-18	-17	-15	-11	-8	-6	-5	-4	-3	-4	-5	-7	-11	-13	-11	-11	-13	-16	-22
0.8	-23	-18	-16	-14	-14	-11	-7	-5	-3	-2	-2	-2	-3	-5	-8	-12	-10	-10	-12	-15	-20
0.4	-22	-17	-14	-12	-13	-11	-7	-4	-2	-1	-1	-1	-2	-4	-7	-10	-9	-9	-11	-14	-19
0.0	-22	-16	-13	-11	-11	-11	-7	-4	-2	-1	0	0	-2	-3	-6	-10	-9	-9	-10	-13	-19
-0.4	-22	-17	-13	-11	-11	-11	-8	-5	-3	-1	-1	-1	-2	-4	-6	-10	-10	-10	-11	-14	-19
-0.8	-23	-17	-13	-12	-11	-12	-10	-6	-4	-3	-2	-2	-3	-5	-7	-11	-12	-11	-13	-15	-20
-1.2	-25	-18	-15	-13	-12	-12	-12	-8	-6	-5	-4	-4	-5	-6	-9	-13	-14	-14	-15	-17	-22
-1.6	-27	-20	-16	-14	-13	-13	-13	-11	-9	-7	-7	-7	-8	-10	-12	-17	-17	-17	-18	-20	-26
-2.0	-28	-22	-18	-16	-15	-14	-13	-12	-11	-10	-10	-10	-11	-12	-15	-26	-18	-19	-21	-23	-30
-2.4	-30	-24	-21	-20	-18	-16	-14	-13	-12	-11	-11	-11	-12	-14	-17	-20	-18	-18	-20	-23	-29
-2.8	-31	-26	-24	-23	-21	-18	-15	-13	-11	-10	-10	-10	-12	-13	-16	-19	-18	-18	-20	-23	-28
-3.2	-33	-28	-25	-24	-24	-20	-17	-14	-12	-11	-11	-11	-13	-14	-17	-20	-19	-19	-21	-24	-29
-3.6	-35	-30	-27	-26	-26	-23	-19	-17	-15	-14	-13	-14	-15	-17	-19	-22	-21	-22	-23	-26	-32

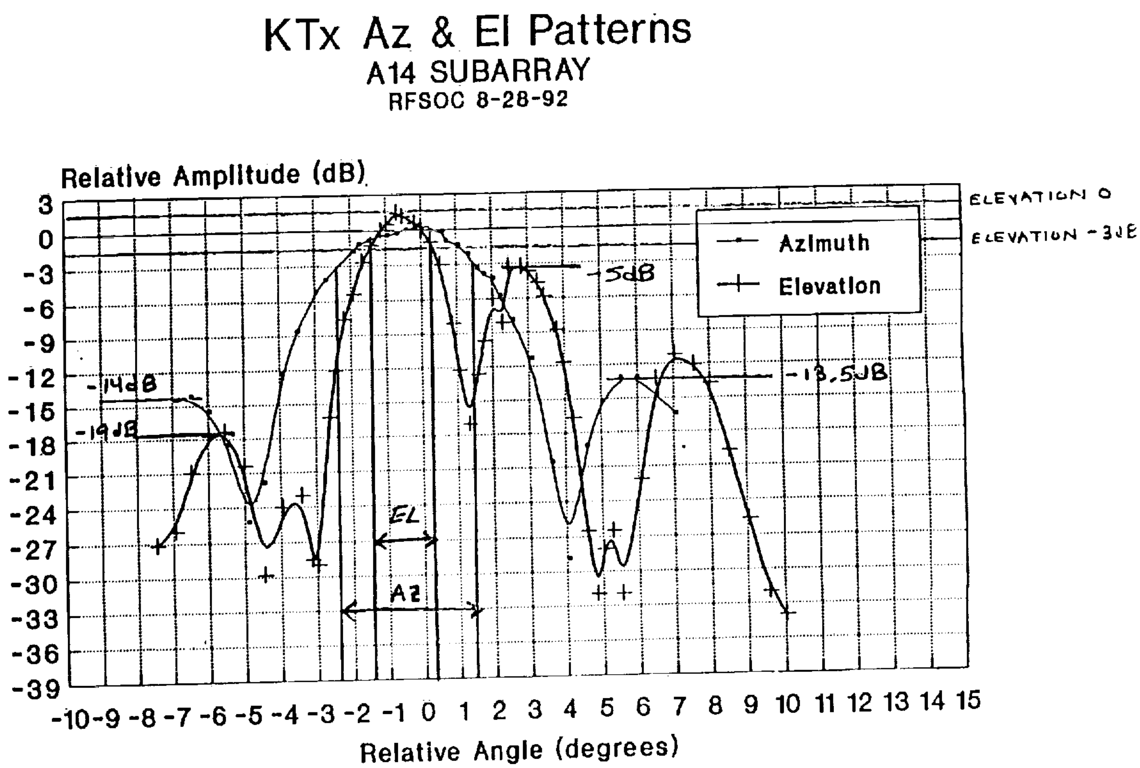
Figure 7. Complete pattern for all elements, exact amplitudes

The overall main-beam gain drops to about 4.6 dB, due to the summation of the less than ideal main-beam gains of each element. This pattern is the best pattern to be expected of the KTx subsystem, provided all elements are co-phased.

III. Non-ideal Phase Application

The pattern presented in Figure 8 was obtained for the KTx with elements 1 & 4 active. It is from this pattern that an off-axis skew of the main beam, and some assymetry in side lobe levels is apparent. The variable that could be manipulated to correct this assymetry is the relative phase between the elements. For example, ASP was asked to show the azimuthal pattern when elements when elements 1 and 4 were cophased 60° behind the 2 and 3 pair. This should result in a beam skewed in azimuth, favoring the 1 and 4 pair. This is precisely what ASP generated, the results of which are indicated in Figure 9.

The next step was to run ASP through several simulations, with elemental phases being modified in a set pattern, to derive the overall relation between misphasing of the elements, and mispointing of the main beam. After several iterations, the following was determined: For every 30° in electrical phase between two elements, the beam would move along a line between the elements 0.15° in spherical coordinates. Additionally, changes in phase between elements had a dramatic effect on the effect of the array factor on those elements, discouraging and encouraging the sidelobe levels of the overall pattern.



DS5 A14

Figure TBD
DS5

File A14828

3 dB BW	AZ	3.8°	
	EL	1.8°	
SLL	AZ	-14 dB	-13.5 dB
	EL	-19 dB	-5 dB

Figure 8. Actual KTx 1 & 4 Combined Pattern[4]

---

[4] Taken from SSG-92-205, pg. 50, Pattern DS-5, Aug 28, 1992

Detailed Printout
Phase 1 = 300.000 degrees, Amplitude 1 = 0.741 (-1.3001 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.661 (-1.8000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.537 (-2.7003 dB)
Phase 4 = 300.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-37	-30	-25	-22	-21	-20	-22	-30	-20	-17	-15	-14	-14	-15	-16	-18	-22	-28	-29	-30	-33
3.2	-33	-27	-22	-19	-17	-16	-17	-21	-17	-14	-11	-11	-11	-11	-13	-15	-18	-25	-28	-27	-30
2.8	-32	-25	-20	-17	-15	-14	-14	-16	-16	-13	-10	-10	-10	-10	-11	-13	-15	-20	-32	-27	-29
2.4	-30	-24	-19	-16	-13	-12	-11	-12	-14	-16	-13	-11	-10	-10	-11	-12	-14	-17	-22	-30	-31
2.0	-28	-22	-19	-17	-15	-13	-11	-11	-12	-12	-12	-14	-18	-21	-17	-19	-15	-17	-19	-23	-30
1.6	-25	-20	-17	-15	-15	-13	-11	-10	-8	-7	-6	-6	-7	-8	-10	-13	-16	-15	-16	-19	-25
1.2	-24	-18	-15	-13	-12	-12	-12	-9	-6	-5	-3	-3	-4	-5	-6	-9	-14	-15	-15	-17	-22
0.8	-23	-17	-13	-11	-10	-10	-11	-8	-5	-3	-2	-2	-2	-3	-4	-7	-12	-15	-14	-16	-20
0.4	-22	-16	-12	-9	-8	-8	-9	-8	-4	-2	-1	0	-1	-2	-3	-5	-10	-14	-13	-15	-19
0.0	-22	-16	-11	-9	-7	-7	-9	-8	-4	-2	0	0	0	-1	-2	-5	-9	-15	-13	-15	-19
-0.4	-23	-16	-12	-9	-8	-7	-8	-8	-5	-3	-1	-1	-1	-2	-3	-5	-9	-15	-14	-16	-20
-0.8	-24	-17	-13	-10	-8	-8	-9	-10	-6	-4	-2	-2	-2	-3	-4	-6	-10	-16	-16	-17	-21
-1.2	-26	-19	-14	-11	-10	-9	-10	-11	-8	-6	-4	-4	-4	-5	-6	-8	-11	-17	-19	-19	-23
-1.6	-27	-21	-16	-13	-12	-11	-11	-13	-11	-9	-7	-7	-7	-8	-9	-12	-14	-19	-23	-23	-26
-2.0	-28	-21	-17	-15	-14	-13	-13	-14	-13	-11	-10	-10	-10	-10	-12	-15	-17	-20	-22	-24	-30
-2.4	-29	-23	-20	-18	-17	-17	-16	-15	-13	-11	-10	-10	-11	-12	-13	-15	-20	-21	-21	-24	-30
-2.8	-30	-24	-21	-19	-18	-19	-18	-16	-13	-11	-10	-10	-10	-11	-13	-15	-20	-22	-22	-24	-29
-3.2	-32	-26	-23	-20	-19	-20	-20	-17	-14	-12	-11	-11	-11	-12	-14	-16	-21	-24	-23	-25	-30
-3.6	-34	-29	-25	-22	-21	-21	-22	-20	-17	-15	-13	-13	-13	-14	-16	-18	-23	-26	-26	-27	-32

Figure 9. Skew demonstration

Figures 10a through 10g are included as a demonstration of this beam steering effect, in which one pair (1,4) of adjacent elements are moved in 30° increments in phase away from the other co-phased pair (2,3). Notice the increase in side lobe levels as the differential becomes larger.

Detailed Printout
Phase 1 = 0.000 degrees, Amplitude 1 = 0.741 (-1.3001 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.661 (-1.8000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.537 (-2.7003 dB)
Phase 4 = 0.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-36	-30	-26	-24	-24	-27	-25	-19	-17	-15	-14	-14	-15	-17	-19	-25	-27	-24	-25	-28	-33
3.2	-32	-26	-22	-20	-19	-21	-22	-16	-13	-12	-11	-11	-12	-13	-15	-21	-25	-21	-22	-24	-29
2.8	-30	-24	-20	-17	-16	-16	-18	-15	-12	-11	-9	-9	-10	-11	-13	-17	-21	-22	-21	-23	-28
2.4	-29	-22	-18	-16	-14	-13	-14	-15	-15	-12	-10	-10	-10	-11	-12	-15	-17	-23	-28	-26	-29
2.0	-29	-22	-18	-16	-14	-12	-12	-12	-13	-14	-16	-18	-17	-15	-15	-18	-15	-17	-20	-25	-30
1.6	-27	-22	-19	-17	-14	-11	-9	-8	-7	-7	-7	-8	-9	-12	-15	-15	-12	-13	-15	-19	-25
1.2	-25	-20	-18	-17	-15	-11	-8	-6	-5	-4	-3	-4	-5	-7	-11	-13	-11	-11	-13	-16	-22
0.8	-23	-18	-16	-14	-14	-11	-7	-5	-3	-2	-2	-2	-3	-5	-8	-12	-10	-10	-12	-15	-20
0.4	-22	-17	-14	-12	-13	-11	-7	-4	-2	-1	-1	-1	-2	-4	-7	-10	-9	-9	-11	-14	-19
0.0	-22	-16	-13	-11	-11	-11	-7	-4	-2	-1	0	0	-2	-3	-6	-10	-9	-9	-10	-13	-19
-0.4	-22	-17	-13	-11	-11	-11	-8	-5	-3	-1	-1	-1	-2	-4	-6	-10	-10	-10	-11	-14	-19
-0.8	-23	-17	-13	-12	-11	-12	-10	-6	-4	-3	-2	-2	-3	-5	-7	-11	-12	-11	-13	-15	-20
-1.2	-25	-18	-15	-13	-12	-12	-12	-8	-6	-5	-4	-4	-5	-6	-9	-13	-14	-14	-15	-17	-22
-1.6	-27	-20	-16	-14	-13	-13	-13	-11	-9	-7	-7	-7	-8	-10	-12	-17	-17	-17	-18	-20	-26
-2.0	-28	-22	-18	-16	-15	-14	-13	-12	-11	-10	-10	-10	-11	-12	-15	-26	-18	-19	-21	-23	-30
-2.4	-30	-24	-21	-20	-18	-16	-14	-13	-12	-11	-11	-11	-12	-14	-17	-20	-18	-18	-20	-23	-29
-2.8	-31	-26	-24	-23	-21	-18	-15	-13	-11	-10	-10	-10	-12	-13	-16	-19	-18	-18	-20	-23	-28
-3.2	-33	-28	-25	-24	-24	-20	-17	-14	-12	-11	-11	-11	-13	-14	-17	-20	-19	-19	-21	-24	-29
-3.6	-35	-30	-27	-26	-26	-23	-19	-17	-15	-14	-13	-14	-15	-17	-19	-22	-21	-22	-23	-26	-32

Figure 10a. 0° difference in phase

Detailed Printout
Phase 1 = 330.000 degrees, Amplitude 1 = 0.741 (-1.3001 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.661 (-1.8000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.537 (-2.7003 dB)
Phase 4 = 330.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-36	-30	-26	-23	-22	-22	-27	-22	-18	-16	-14	-14	-15	-16	-17	-21	-26	-27	-26	-28	-33
3.2	-33	-26	-22	-19	-18	-18	-21	-19	-14	-12	-11	-11	-11	-12	-14	-17	-22	-26	-24	-25	-29
2.8	-31	-24	-20	-17	-15	-15	-16	-18	-14	-11	-10	-9	-10	-10	-12	-15	-18	-27	-24	-25	-28
2.4	-30	-23	-18	-16	-14	-12	-12	-14	-16	-14	-11	-10	-10	-10	-11	-13	-15	-19	-26	-30	-30
2.0	-29	-23	-19	-16	-14	-12	-12	-12	-12	-13	-14	-16	-20	-17	-16	-19	-15	-17	-20	-24	-30
1.6	-26	-21	-18	-17	-15	-12	-10	-9	-7	-7	-6	-7	-8	-10	-13	-16	-14	-14	-16	-19	-25
1.2	-24	-19	-16	-14	-14	-13	-10	-7	-5	-4	-3	-4	-4	-6	-8	-11	-13	-13	-14	-16	-22
0.8	-23	-18	-14	-12	-12	-12	-9	-6	-4	-3	-2	-2	-3	-4	-6	-9	-12	-12	-12	-15	-20
0.4	-22	-16	-13	-11	-10	-11	-9	-5	-3	-2	0	-1	-1	-3	-5	-8	-12	-11	-12	-14	-19
0.0	-22	-16	-12	-10	-9	-10	-10	-5	-3	-1	0	0	-1	-2	-4	-7	-12	-11	-12	-14	-19
-0.4	-22	-16	-12	-10	-9	-9	-10	-6	-3	-2	-1	-1	-1	-3	-4	-8	-12	-12	-12	-15	-19
-0.8	-24	-17	-13	-11	-9	-10	-11	-8	-5	-3	-2	-2	-2	-4	-5	-9	-13	-14	-14	-16	-20
-1.2	-25	-19	-14	-12	-10	-10	-12	-10	-7	-5	-4	-4	-4	-5	-7	-11	-14	-17	-16	-18	-22
-1.6	-27	-20	-16	-14	-12	-12	-13	-12	-10	-8	-7	-7	-7	-8	-10	-15	-17	-20	-20	-21	-26
-2.0	-28	-22	-18	-15	-14	-14	-14	-13	-11	-10	-10	-10	-10	-11	-13	-18	-18	-20	-22	-24	-30
-2.4	-30	-24	-21	-19	-18	-17	-15	-14	-12	-11	-10	-11	-11	-13	-15	-17	-20	-19	-21	-23	-29
-2.8	-31	-25	-22	-21	-20	-19	-16	-14	-12	-11	-10	-10	-11	-12	-14	-17	-20	-19	-20	-23	-28
-3.2	-32	-27	-24	-22	-21	-21	-18	-15	-13	-12	-11	-11	-12	-13	-15	-18	-21	-21	-22	-24	-29
-3.6	-35	-29	-26	-24	-23	-24	-21	-18	-15	-14	-13	-13	-14	-15	-17	-20	-24	-23	-24	-27	-32

Figure 10b. 30° difference in phase

Detailed Printout
Phase 1 = 300.000 degrees, Amplitude 1 = 0.741 (-1.3001 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.661 (-1.8000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.537 (-2.7003 dB)
Phase 4 = 300.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-37	-30	-25	-22	-21	-20	-22	-30	-20	-17	-15	-14	-14	-15	-16	-18	-22	-28	-29	-30	-33
3.2	-33	-27	-22	-19	-17	-16	-17	-21	-17	-14	-11	-11	-11	-11	-13	-15	-18	-25	-28	-27	-30
2.8	-32	-25	-20	-17	-15	-14	-14	-16	-16	-13	-10	-10	-10	-10	-11	-13	-15	-20	-32	-27	-29
2.4	-30	-24	-19	-16	-13	-12	-11	-12	-14	-16	-13	-11	-10	-10	-11	-12	-14	-17	-22	-30	-31
2.0	-28	-22	-19	-17	-15	-13	-11	-11	-12	-12	-12	-14	-18	-21	-17	-19	-15	-17	-19	-23	-30
1.6	-25	-20	-17	-15	-15	-13	-11	-10	-8	-7	-6	-6	-7	-8	-10	-13	-16	-15	-16	-19	-25
1.2	-24	-18	-15	-13	-12	-12	-12	-9	-6	-5	-3	-3	-4	-5	-6	-9	-14	-15	-15	-17	-22
0.8	-23	-17	-13	-11	-10	-10	-11	-8	-5	-3	-2	-2	-2	-3	-4	-7	-12	-15	-14	-16	-20
0.4	-22	-16	-12	-9	-8	-8	-9	-8	-4	-2	-1	0	-1	-2	-3	-5	-10	-14	-13	-15	-19
0.0	-22	-16	-11	-9	-7	-7	-9	-8	-4	-2	0	0	0	-1	-2	-5	-9	-15	-13	-15	-19
-0.4	-23	-16	-12	-9	-8	-7	-8	-8	-5	-3	-1	-1	-1	-2	-3	-5	-9	-15	-14	-16	-20
-0.8	-24	-17	-13	-10	-8	-8	-9	-10	-6	-4	-2	-2	-2	-3	-4	-6	-10	-16	-16	-17	-21
-1.2	-26	-19	-14	-11	-10	-9	-10	-11	-8	-6	-4	-4	-4	-5	-6	-8	-11	-17	-19	-19	-23
-1.6	-27	-21	-16	-13	-12	-11	-11	-13	-11	-9	-7	-7	-7	-8	-9	-12	-14	-19	-23	-23	-26
-2.0	-28	-21	-17	-15	-14	-13	-13	-14	-13	-11	-10	-10	-10	-10	-12	-15	-17	-20	-22	-24	-30
-2.4	-29	-23	-20	-18	-17	-17	-16	-15	-13	-11	-10	-10	-11	-12	-13	-15	-20	-21	-21	-24	-30
-2.8	-30	-24	-21	-19	-18	-19	-18	-16	-13	-11	-10	-10	-10	-11	-13	-15	-20	-22	-22	-24	-29
-3.2	-32	-26	-23	-20	-19	-20	-20	-17	-14	-12	-11	-11	-11	-12	-14	-16	-21	-24	-23	-25	-30
-3.6	-34	-29	-25	-22	-21	-21	-22	-20	-17	-15	-13	-13	-13	-14	-16	-18	-23	-26	-26	-27	-32

Figure 10c. 60° difference in phase

Detailed Printout
Phase 1 = 270.000 degrees, Amplitude 1 = 0.741 (-1.3001 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.661 (-1.8000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.537 (-2.7003 dB)
Phase 4 = 270.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-38	-30	-25	-22	-20	-19	-19	-21	-27	-19	-16	-14	-14	-15	-15	-17	-20	-24	-30	-32	-34
3.2	-34	-27	-22	-18	-16	-15	-15	-16	-21	-16	-12	-11	-11	-11	-12	-13	-16	-20	-28	-30	-31
2.8	-32	-25	-20	-16	-14	-13	-12	-13	-16	-15	-12	-10	-10	-10	-10	-12	-14	-18	-23	-33	-30
2.4	-29	-24	-19	-16	-13	-12	-11	-11	-12	-14	-16	-13	-11	-10	-10	-12	-13	-16	-19	-25	-35
2.0	-26	-21	-19	-17	-15	-13	-12	-11	-11	-11	-11	-12	-15	-19	-19	-18	-16	-17	-19	-22	-30
1.6	-24	-19	-16	-14	-13	-13	-12	-11	-9	-7	-6	-6	-6	-7	-9	-11	-16	-18	-17	-19	-25
1.2	-23	-17	-14	-11	-10	-10	-11	-11	-8	-5	-3	-3	-3	-4	-5	-7	-11	-18	-17	-18	-23
0.8	-22	-16	-12	-10	-8	-8	-9	-9	-7	-4	-2	-1	-2	-2	-3	-5	-9	-16	-16	-17	-21
0.4	-22	-16	-11	-9	-7	-6	-7	-8	-6	-3	-1	0	-1	-1	-2	-4	-7	-13	-16	-16	-20
0.0	-22	-16	-11	-8	-6	-5	-6	-8	-6	-3	-1	0	0	0	-1	-3	-6	-12	-17	-16	-20
-0.4	-23	-17	-12	-8	-6	-6	-6	-7	-7	-4	-1	-1	-1	-1	-2	-4	-7	-12	-18	-17	-20
-0.8	-24	-18	-13	-9	-7	-6	-6	-8	-8	-5	-3	-2	-2	-2	-3	-5	-8	-12	-19	-19	-22
-1.2	-26	-19	-14	-11	-9	-8	-8	-9	-10	-7	-5	-4	-4	-4	-5	-7	-9	-14	-20	-21	-24
-1.6	-27	-21	-16	-13	-11	-10	-10	-11	-13	-10	-8	-7	-7	-7	-8	-10	-12	-16	-22	-25	-27
-2.0	-27	-21	-17	-14	-13	-12	-12	-13	-14	-12	-10	-10	-9	-10	-11	-13	-15	-19	-22	-25	-31
-2.4	-28	-22	-19	-17	-16	-16	-16	-16	-14	-12	-11	-10	-10	-11	-12	-13	-18	-24	-23	-24	-30
-2.8	-29	-24	-20	-18	-16	-16	-17	-17	-14	-12	-10	-10	-10	-10	-11	-13	-17	-24	-24	-24	-29
-3.2	-31	-26	-22	-19	-17	-17	-18	-19	-16	-13	-11	-11	-11	-11	-12	-14	-18	-25	-25	-26	-30
-3.6	-34	-28	-24	-21	-20	-19	-20	-21	-18	-15	-13	-13	-13	-14	-15	-16	-20	-26	-28	-28	-32

Figure 10d. 90° difference in phase

Detailed Printout
Phase 1 = 240.000 degrees, Amplitude 1 = 0.741 (-1.3001 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.661 (-1.8000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.537 (-2.7003 dB)
Phase 4 = 240.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-39	-31	-26	-22	-19	-18	-17	-18	-21	-24	-17	-15	-14	-14	-15	-16	-18	-22	-27	-34	-36
3.2	-35	-29	-22	-18	-15	-14	-13	-14	-16	-20	-14	-12	-11	-11	-11	-12	-15	-18	-23	-33	-33
2.8	-31	-26	-21	-17	-14	-12	-11	-11	-13	-15	-14	-11	-10	-10	-10	-11	-13	-16	-20	-27	-34
2.4	-28	-23	-20	-16	-14	-11	-10	-10	-10	-11	-14	-16	-12	-11	-10	-11	-12	-15	-18	-23	-35
2.0	-26	-20	-18	-16	-15	-14	-12	-11	-11	-10	-10	-11	-13	-15	-18	-17	-17	-17	-19	-22	-30
1.6	-24	-18	-15	-13	-12	-12	-12	-12	-10	-8	-6	-6	-6	-6	-7	-9	-13	-22	-19	-20	-26
1.2	-23	-17	-13	-10	-9	-8	-8	-9	-10	-6	-4	-3	-3	-3	-4	-6	-9	-14	-21	-19	-24
0.8	-22	-16	-12	-9	-7	-6	-6	-7	-8	-5	-3	-2	-1	-2	-2	-4	-7	-11	-19	-19	-22
0.4	-22	-16	-11	-8	-6	-5	-5	-5	-7	-5	-2	-1	0	-1	-1	-3	-5	-10	-17	-19	-21
0.0	-22	-16	-11	-7	-5	-4	-4	-5	-7	-5	-2	0	0	0	-1	-2	-5	-9	-15	-19	-21
-0.4	-23	-17	-12	-8	-6	-5	-4	-5	-7	-6	-2	-1	-1	-1	-1	-3	-5	-9	-15	-20	-22
-0.8	-25	-18	-13	-9	-7	-5	-5	-5	-7	-7	-4	-2	-2	-2	-2	-4	-6	-10	-15	-22	-23
-1.2	-26	-20	-15	-11	-8	-7	-6	-7	-9	-9	-6	-4	-4	-4	-4	-6	-8	-11	-17	-24	-25
-1.6	-26	-21	-16	-13	-11	-9	-9	-9	-11	-12	-9	-8	-7	-7	-7	-9	-11	-14	-19	-25	-28
-2.0	-26	-20	-17	-14	-12	-11	-11	-12	-14	-13	-11	-10	-9	-9	-10	-12	-14	-18	-21	-25	-32
-2.4	-27	-22	-18	-16	-15	-14	-14	-15	-16	-13	-11	-10	-10	-10	-11	-12	-16	-22	-25	-26	-32
-2.8	-29	-23	-19	-17	-15	-15	-15	-15	-16	-13	-11	-10	-10	-10	-11	-12	-15	-20	-27	-26	-30
-3.2	-31	-25	-21	-18	-16	-16	-16	-16	-17	-15	-12	-11	-11	-11	-12	-13	-16	-21	-28	-28	-31
-3.6	-34	-28	-24	-21	-19	-18	-18	-18	-19	-17	-14	-13	-13	-13	-14	-15	-18	-22	-29	-31	-34

Figure 10e. 120° difference in phase

Detailed Printout
Phase 1 = 210.000 degrees, Amplitude 1 = 0.741 (-1.3001 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.661 (-1.8000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.537 (-2.7003 dB)
Phase 4 = 210.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-42	-33	-26	-22	-19	-17	-16	-16	-17	-21	-21	-17	-15	-14	-14	-15	-17	-20	-24	-31	-38
3.2	-34	-31	-23	-18	-15	-13	-12	-12	-13	-16	-19	-13	-12	-11	-11	-12	-14	-17	-21	-27	-39
2.8	-30	-25	-22	-17	-14	-12	-10	-10	-11	-12	-15	-13	-11	-10	-10	-10	-12	-15	-18	-24	-38
2.4	-27	-21	-19	-17	-14	-12	-10	-9	-9	-10	-11	-15	-15	-12	-11	-11	-12	-14	-17	-21	-31
2.0	-25	-19	-17	-15	-15	-14	-12	-12	-11	-10	-10	-10	-11	-13	-15	-15	-19	-18	-19	-22	-30
1.6	-23	-17	-14	-12	-11	-10	-10	-11	-11	-9	-7	-6	-6	-6	-7	-8	-11	-17	-25	-22	-27
1.2	-23	-17	-13	-10	-8	-7	-7	-7	-8	-8	-5	-4	-3	-3	-4	-5	-7	-11	-18	-23	-26
0.8	-22	-16	-12	-9	-6	-5	-5	-5	-6	-7	-4	-2	-2	-2	-2	-3	-5	-9	-15	-22	-25
0.4	-22	-16	-11	-8	-5	-4	-3	-3	-5	-6	-3	-2	-1	0	-1	-2	-4	-8	-13	-20	-24
0.0	-23	-16	-11	-7	-5	-2	-2	-2	-4	-6	-4	-1	0	0	0	-1	-3	-7	-12	-19	-24
-0.4	-24	-18	-12	-8	-5	-4	-3	-3	-4	-6	-4	-2	-1	-1	-1	-2	-4	-7	-12	-19	-25
-0.8	-24	-19	-14	-9	-6	-5	-4	-4	-5	-7	-6	-3	-2	-2	-2	-3	-5	-8	-13	-19	-26
-1.2	-25	-20	-15	-11	-8	-6	-5	-5	-6	-8	-8	-6	-4	-4	-4	-5	-7	-10	-14	-20	-29
-1.6	-25	-20	-17	-13	-10	-9	-8	-8	-9	-11	-11	-9	-7	-7	-7	-8	-10	-13	-17	-22	-31
-2.0	-25	-20	-17	-14	-12	-11	-10	-10	-12	-13	-12	-11	-10	-9	-10	-11	-13	-17	-20	-24	-36
-2.4	-27	-21	-18	-15	-14	-13	-13	-13	-15	-15	-12	-11	-10	-10	-11	-12	-14	-19	-26	-28	-35
-2.8	-29	-23	-19	-16	-14	-13	-13	-13	-14	-15	-12	-10	-10	-10	-10	-11	-14	-17	-23	-30	-33
-3.2	-31	-25	-21	-18	-16	-14	-14	-14	-15	-16	-13	-11	-11	-11	-11	-12	-14	-18	-24	-31	-34
-3.6	-35	-28	-24	-20	-18	-17	-16	-16	-17	-18	-16	-14	-13	-13	-13	-14	-17	-20	-25	-33	-36

Figure 10f. 150° difference in phase

Detailed Printout
Phase 1 = 180.000 degrees, Amplitude 1 = 0.741 (-1.3001 dB)
Phase 2 = 0.000 degrees, Amplitude 2 = 0.661 (-1.8000 dB)
Phase 3 = 0.000 degrees, Amplitude 3 = 0.537 (-2.7003 dB)
Phase 4 = 180.000 degrees, Amplitude 4 = 1.000 (0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments: Levels in dB below reference, -3dB and -10 dB contours indicated

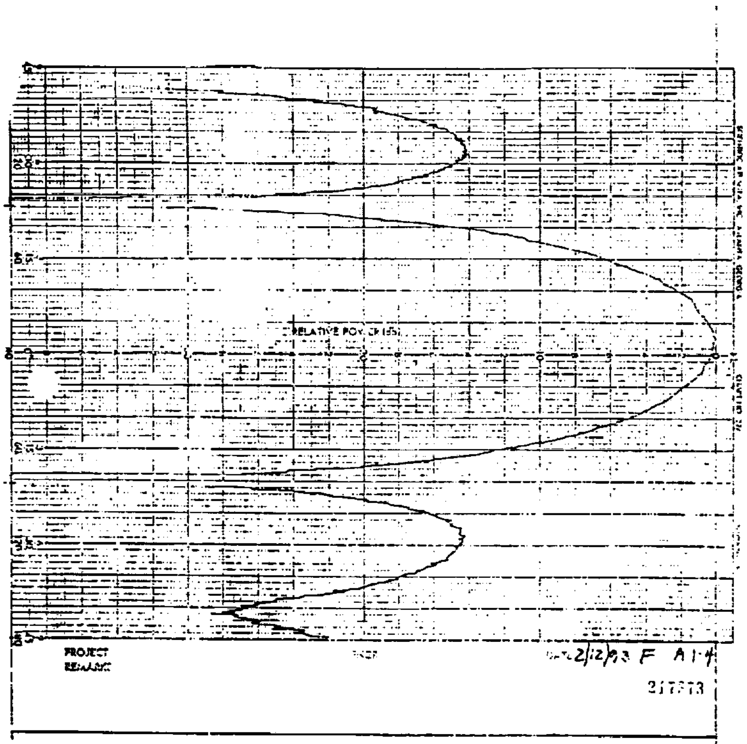
	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-39	-39	-28	-22	-19	-17	-15	-15	-15	-17	-21	-20	-16	-15	-14	-15	-16	-19	-23	-28	-36
3.2	-32	-30	-26	-19	-15	-13	-12	-11	-11	-12	-16	-17	-13	-11	-11	-11	-13	-15	-19	-24	-33
2.8	-28	-24	-23	-18	-14	-12	-10	-9	-9	-10	-12	-16	-13	-11	-10	-10	-11	-14	-17	-22	-31
2.4	-26	-20	-18	-17	-15	-12	-10	-9	-8	-8	-9	-11	-16	-14	-12	-11	-12	-14	-16	-20	-28
2.0	-24	-18	-16	-14	-14	-14	-13	-13	-12	-10	-9	-10	-11	-12	-13	-14	-24	-18	-19	-22	-30
1.6	-23	-17	-14	-11	-10	-9	-8	-9	-10	-11	-8	-6	-6	-6	-6	-7	-10	-14	-20	-25	-30
1.2	-23	-16	-12	-9	-7	-6	-5	-5	-6	-8	-7	-5	-4	-3	-3	-4	-6	-9	-14	-22	-32
0.8	-23	-16	-12	-8	-6	-4	-3	-3	-4	-6	-6	-4	-2	-2	-2	-2	-4	-7	-12	-18	-30
0.4	-23	-16	-11	-8	-5	-3	-2	-2	-2	-4	-5	-3	-1	-1	0	-1	-3	-6	-10	-16	-28
0.0	-23	-17	-12	-7	-4	-3	-1	-1	-1	-3	-5	-3	-1	0	0	-1	-2	-5	-9	-15	-27
-0.4	-23	-19	-13	-8	-5	-3	-2	-1	-2	-3	-5	-4	-2	-1	-1	-1	-3	-6	-10	-15	-26
-0.8	-23	-19	-15	-10	-6	-4	-3	-2	-3	-4	-6	-5	-3	-2	-2	-2	-4	-7	-11	-16	-27
-1.2	-23	-19	-16	-11	-8	-6	-5	-4	-4	-6	-8	-7	-5	-4	-4	-4	-6	-9	-12	-17	-29
-1.6	-24	-19	-17	-13	-10	-8	-7	-7	-7	-9	-11	-10	-8	-7	-7	-7	-9	-12	-15	-20	-33
-2.0	-25	-19	-16	-14	-11	-10	-9	-9	-10	-11	-13	-12	-10	-10	-10	-11	-12	-16	-19	-23	-39
-2.4	-27	-21	-17	-15	-13	-12	-11	-11	-12	-14	-14	-12	-11	-10	-10	-11	-13	-17	-22	-28	-38
-2.8	-29	-23	-19	-16	-14	-12	-11	-11	-12	-14	-14	-11	-10	-10	-10	-10	-12	-16	-20	-27	-37
-3.2	-32	-25	-21	-17	-15	-13	-13	-12	-13	-15	-15	-13	-11	-11	-11	-11	-13	-17	-21	-27	-38
-3.6	-35	-29	-24	-20	-17	-16	-15	-14	-15	-17	-17	-15	-14	-13	-13	-14	-16	-19	-23	-29	-39

Figure 10g. 180° difference in phase

IV. Application to the Hardware

The next step was to apply these results to the re-tuning of the pattern for the KTx subsystem, through careful manipulation of the inline mechanical phase shifters. Unfortunately, the power amplifier driving element A2 (A3 in SSG docs) failed, leaving only elements 1, 3, and 4 with which to work with. Applying the expected amount of phase in the 1,4 combination's feed network resulted in the following pattern improvement in Figure 11.

Pattern 212F, A14



Pattern 302D, A14

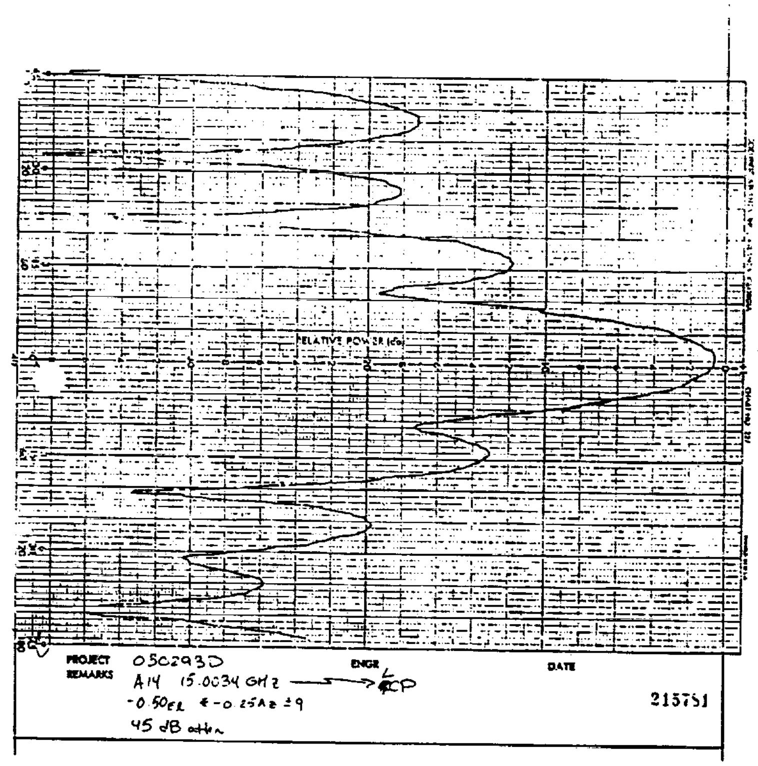


Figure 11. 1 & 4 actual phased pattern[5]

[5] Taken from TSG-93-75, pg. 4-24, Pattern 212F/302D, March 2, 1993

Returning to ASP for a "14" co-phased estimate reported the following predicted pattern:

```
Detailed Printout
Phase 1 =  0.000 degrees, Amplitude 1 =   1.000 (  0.0000 dB)
Phase 2 =  0.000 degrees, Amplitude 2 =   0.000 (-999.0000 dB)
Phase 3 =  0.000 degrees, Amplitude 3 =   0.000 (-999.0000 dB)
Phase 4 =  0.000 degrees, Amplitude 4 =   1.000 (  0.0000 dB)

Azimuth is horizontal, and elevation vertical.

Comments:  Levels in dB below reference, -3dB and -10 dB contours indicated
```

	-4.0	-3.6	-3.2	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
3.6	-36	-31	-27	-24	-22	-20	-18	-17	-16	-16	-15	-15	-16	-16	-17	-18	-19	-22	-25	-28	-34
3.2	-32	-26	-23	-20	-17	-15	-14	-13	-12	-12	-11	-11	-12	-12	-13	-14	-15	-18	-21	-24	-30
2.8	-29	-23	-20	-17	-15	-13	-12	-11	-10	-10	-9	-10	-10	-11	-11	-12	-14	-16	-19	-23	-28
2.4	-27	-21	-18	-16	-14	-13	-12	-11	-11	-10	-10	-10	-11	-11	-12	-13	-14	-17	-20	-23	-29
2.0	-26	-20	-17	-15	-14	-14	-13	-16	-17	-17	-14	-14	-14	-15	-14	-13	-19	-20	-23	-29	-29
1.6	-25	-18	-15	-13	-11	-10	-9	-8	-7	-7	-6	-7	-7	-8	-8	-9	-11	-13	-16	-20	-25
1.2	-23	-18	-14	-12	-9	-8	-6	-5	-4	-4	-3	-4	-4	-5	-5	-6	-8	-10	-13	-17	-22
0.8	-22	-17	-13	-10	-8	-6	-5	-3	-3	-2	-2	-2	-2	-3	-3	-4	-6	-8	-11	-15	-21
0.4	-21	-16	-13	-9	-7	-5	-4	-2	-1	-1	0	-1	-1	-2	-2	-3	-5	-7	-10	-14	-19
0.0	-21	-16	-12	-9	-6	-5	-4	-2	-1	-1	0	0	-1	-1	-2	-3	-4	-7	-10	-13	-19
-0.4	-22	-16	-13	-10	-7	-5	-4	-2	-2	-1	-1	-1	-1	-2	-2	-3	-5	-7	-10	-14	-19
-0.8	-22	-17	-13	-10	-8	-6	-5	-4	-3	-2	-2	-2	-2	-3	-3	-4	-6	-8	-11	-15	-21
-1.2	-24	-18	-14	-12	-10	-8	-7	-5	-5	-4	-4	-4	-4	-5	-5	-6	-8	-10	-13	-17	-22
-1.6	-25	-19	-16	-14	-12	-10	-9	-9	-8	-8	-7	-7	-8	-8	-9	-10	-11	-14	-17	-20	-26
-2.0	-26	-20	-16	-15	-13	-12	-11	-12	-12	-12	-13	-13	-13	-14	-15	-20	-16	-20	-22	-25	-37
-2.4	-28	-22	-19	-17	-15	-14	-13	-12	-12	-11	-11	-11	-11	-12	-12	-13	-15	-17	-20	-24	-29
-2.8	-30	-24	-20	-18	-16	-14	-13	-12	-11	-10	-10	-10	-10	-11	-11	-12	-14	-17	-19	-23	-28
-3.2	-32	-26	-23	-20	-17	-15	-14	-13	-12	-11	-11	-11	-11	-12	-12	-13	-15	-18	-20	-24	-30
-3.6	-34	-29	-25	-22	-19	-18	-16	-15	-14	-13	-13	-13	-13	-14	-14	-15	-17	-20	-22	-26	-32

Figure 12. 1 & 4 predicted pattern from ASP

V. Summary

ASP expertly assisted in the diagnosing of phase shifter errors during KTx testing. Additionally, the software was able to correctly estimate the effect of phase shift on the overall array pattern developed from each of the internally held element patterns. It would have been advantageous to work with the complete KTx array, with all elements operating, but due to system failures, this level of analysis was not supported.

VI. Future Applications

A specially modified version of ASP has been used to obtain predictions for XTE solar sail blockage effects, including interferometer peaking due to solar sail reflection. Future applications for Space Network projects may include diffraction effects for communications regions directly blocked by the XTE solar panels, cross polarized pattern predictions, antenna squint determination, axial ratio calculations, pattern normalcy (null suggested beamwidths versus actual beamwidth) and diskette loadable antenna patterns.

Simulation may even be further extended through the addition of TDRSS link simulation code, allowing the user to identify degradation in service due to misphasing or misalignment,

with a standard six-element based set of orbital dynamics calculations.

ASP generates several outputs, including a variable sweep (azimuth and elevation) on-screen display, a KTx specific printed sweep, elevation and azimuth cuts to ASCII files (Lotus and Quattro compatible), and an XTE specific contour plot designed to demonstrate solar panel interference.

Allen David Snook, was born in Fall River, Massachusetts on February 15, 1970. He received the B.S. degree in Electrical Engineering from Virginia Polytechnic Institute and State University. He joined the Loral Aerosys SEAS contract in 1992. His main area of interest is theoretical electromagnetics, and the application of computer and software toward solution of electromagnetics problems.